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ABSTRACT

The research question addressed in this study was: "How do the problem-solving heuristic processes used by preservice elementary teachers who are more effective problem solvers differ from those used by less effective problem solvers?" Three more- and three less-effective problem solvers performed a card sorting task designed to determine if subjects categorize mathematical problems according to their mathematical structure or according to the contexual setting of the problem. Findings from the study are listed and questions are formulated for further research. One of these is whether or not instruction emphasizing the heuristic processes of analysis, deduction, modeling, planning, and trial and error improve the problem-solving abilities of preservice elementary teachers. (JD)

AN EXPLORATORY STUDY OF MATHEMATICAL PROBLEM SOLVING WITH PRE-SERVICE ELEMENTARY TEACHERS

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Problem solving has been a major focus in mathematics education for over a decade. An Agenda for Action (NCTM, 1980) proposed that "problem solving must be the focus of school mathematics in the 1980's." More currently in Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989), problem solving along with communication, connections, and logical thinking are set forth as the first four standards for mathematics education at all grade levels. If problem solving is to be a priority in elementary mathematics, we must provide instruction for pre-service elementary teachers that will help them develop their own problem-solving skills because "in order to teach problem solving effectively, teachers must have confidence in their own problem-solving ability" (Lane Education Service District, 1983).

A review of the literature on problem solving related to pre-service elementary teachers failed to reveal a significant body of background knowledge about the problem-solving processes in this population. Thus the broad research question addressed in this study was:

> How do the problem-solving heuristic processes used by pre-service elementary teachers who are more effective problem solvers differ from those used by less effective problem solvers in this group?

The following operational definitions were used in this study.

1. A pre-service elementary teacher is a college student who has declared an elementary education major.

2. A problem is a mathematical situation in which a task is to be performed for which there is no readily accessible algorithm which determines completely the solution process.

3. A heuristic process is the sequence of actions taken in attempting to create an algorithm for solving a problem. Kantowski (1980) has identified fourteen heuristic processes.

4. More and less effective problem solvers are defined according to their performance on the test created for this purpose.

The first step in this study was to identify more and less effective problem solvers within the accessible sample of pre-

service elementary teachers. Three more effective and three less effective problem solvers were selected as subjects for the study. Eighty-five students enrolled in two sections of the mathematics course for elementary education majors at The University of Texas at Austin were tested. The participation of the three students scoring the highest and the three students scoring the lowest was elicited.

Two sessions, each of approximately one hour duration, were held with each subject individually. In the first session each subject was asked to fill out a questionnaire describing her mathematics background, perform a card sorting task created by the researcher based on the work of Silver (1979, 1981), and solve two practice problems using the think-aloud procedure. In the second session each subject was asked to solve the nine problems from the card sorting task while thinking aloud, and then perform the card sorting task a second time.

The card sorting task was scored using the system created by Silver. The think-aloud narratives were coded using the coding system created by Lucas, Kantowski, Branca, Kellog, Goldberg, and Smith (1979). Due to the sample size and the exploratory nature of this study, data analysis was limited to identifying similarities and differences between more effective and less effective subjects.

The card sorting task is designed to determine if subjects categorize mathematical problems according to their mathematical structure or according to the contextual setting of the problem. The first time the card sorting task was performed, only one subject, Subject 2, sorted the cards in such a way as to indicate total recognition of all the structural relationships. Subject 2 was also the only subject to solve all nine problems completely and correctly. One of the more effective (Subject 4) and one of the less effective (Subject 1) subjects sorted the cards in such a way as to indicate they were sorting completely according to contextual relationships. Subject 5 (more effective) and Subject 6 (less effective) sorted totally according to structure, although their sorts indicated that they did not perceive all the structural relationships. The results of the first card sorting task were mixed for Subject 3 (less effective).

After the subjects had attempted to solve the problems they performed the card sorting task a second time. Five of the six subjects sorted in such as was on this second sort as to indicate that they were had discovered all the relationships in mathematical structure for the nine problem. Although Subject 6 (less effective) did sort totally according to mathematical structure she did not recognize all the structural relationships.

As was expected the more effective problem solvers completely and correctly solved more problems that the less effective problem solvers. However, two interesting results were found in this area. Subject 3 was classified as a less effective problem solvers yet she solved 8 of the nine problems given correctly. However, her

solution processes did differ from the more effective problem solvers. Subject 5 was classified as a more effective problem solver yet she solved only 6 of the problems given completely. She did solve all the problems correctly, however failed to state her answers in such a way as to completely answer the question asked on three of the problem. The results of the card sorting task are detailed in Table 1. This table also shows the number of problems correctly solved by each subject.

The process sequence codes produced by coding the think aloud narratives revealed the following.

1. The process sequence codes were longer for the less effective subjects.

2. More instances of questioning were recorded for the less effective subjects.

3. The less effective subjects spent more time and effort analyzing the problems than more effective subjects.

4. The more effective subjects used modeling slightly more than the less effective subjects.

5. There was very little difference in the use of analogy between the two groups.

6. The more effective subjects planned slightly more than the less effective subjects.

7. The less effective subjects used slightly more deductive processes than the more effective subjects.

8. The less effective subjects made more errors in deductive processes than the more effective subjects.

9. The less effective subjects used slightly more looking back processes than the more effective subjects.

10. There was very little difference in the use of symbolism between the two groups.

11. The less effective subjects were coded as using more algorithms.

12. The less effective subjects made more errors in using algorithms than the more effective subjects.

Due to the exploratory nature of this study, its main purpose was to help formulate questions for future research. The following questions are among those that seem to be indicated by the results of this study.

1. Will instruction emphasizing the heuristic processes of analysis, deduction, modeling, planning and trail and error improve the problem solving abilities of pre-service elementary teachers?

2. Will instruction using card sorting tasks in conjunction with attempting to solve problems facilitate discovery of mathematical structural relationships?

Table 1

Results of Card Sorting Task

Subject	Card Sort 1 Groupings	Card Sort 1 Context Association	Card Sort 1 Context Pure	Card Sort 1 Structure Association	Card Sort 1 Structure Pure	Card Sort 2 Groupings	Card Sort 2 Context Association	Card Sort 2 Context Pure	Card Sort 2 Structure Association	Card Sort 2 Structure Pure	Problem Solving Score
1 Less Eff.	(6,7,8) (4,9,1) (2,3,5)	9	3	0	0	(9,3,8) (2,7,4) (5,6,1)	0	0	9	3	3
3 Less Eff.	(1,9,3) (7,4,2) (6,8,5)	2	0	5	1	(9,3,8) (7,4,2) (5,6,1)	0	0	9	3	8
6 Less Eff.	(3,9)(8) (2,7,4) (6,1,5)	0	0	7	3	(9,8)(3) (5,6)(1) (7,2,4)	0	0	5	3	2
2 More Eff.	(1,6,5) (7,4,2) (3,9,8)	0	0	9	3	(1,6,5) (7,4,2) (3,9,8)	0	0	9	3	9
4 More Eff.	(3,2,5) (1,4,9) (6,7,8)	9	3	0	0	(3,8,9) (1,5,6) (2,4,7)	0	0	9	3	8
5 More Eff.	(2,4,7) (1,5,6) (9,3)(8)	0	0	7	3	(9,3,8) (2,7,4) (5,6,1)	0	0	9	3	6

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